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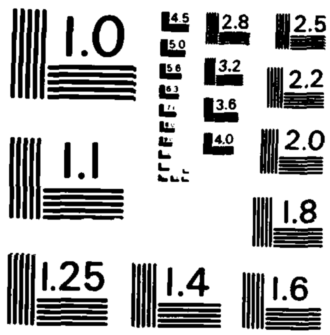


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

# The STATE Experiment - Overview

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## Abstract

The STructure and Atmospheric Turbulence Environment (STATE) experiment was conducted at Poker Flat Research Range, Alaska during the first two weeks of June 1983. *In situ* measurements of the atmospheric properties have been compared to the MST radar signals in an effort to interpret the dynamical conditions in the middle atmosphere. The measurements were made during the summer season at PFRR based on the large signals which have been measured by the MST radar over the past several years. Rockets with probes which can measure the electron irregularities with high spatial resolution were launched on three occasions which corresponded to selected conditions observed in real time in the radar data. In one of these cases, several other instruments were launched to study the structure of the neutral atmosphere. Profiles of density, temperature, wind and turbulence properties were measured. This paper describes the experiment and introduces the several scientific papers to follow.



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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Structure and Atmospheric Turbulence Environment (STATE) experiment was conducted at Poker Flat Research Rnage, Alaska during the first two weeks of June 1983. In situ measurements of the atmospheric properties have been compared to the MST radar signals in an effort to interpret the dynamical conditions in the middle atmosphere. The measurements were made during the summer season at PFRR based on the large signals which have been measured by the MST radar over the past several years. Rockets with probes which can measure the electron irregularities with high spatial resolution were launched on three occasions which corresponded to selected conditions observed in real time in the rada data. In one of the these cases, several other instruments were launched to study the structure of the neutal atmosphere. Profiles of density, temperature, wind and turbulence properties were measured. This paper describes the experiment and introduces the several scientific papers to follow.

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SECURITY CLASSIFICATION OF THIS PAGE

Comparison of Rocket-Probe Electron Density and MST Radar Polar Mesospheric Measurements

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A companion paper presented spectra from rocket-borne measurements of electron density fluctuations. Using the spectra from the STATE 1 rocket, we show that the viscous cut off scales with turbulence strength in exactly the way predicted by theory. We present the integrated $(\Delta N)^2$ power at 3 m ± 20% for each 1/4 sec. (approximately 100 m) spectrum from the three rocket flights compared to the corresponding MST radar echo signal-to-noise measurements. The $(\Delta N)^2$ power plots are clearly co-located with the origin of the simultaneously measured radar backscatter signals. However, the rocket data shows much more structure variations within the radar measured turbulent layer, although in one case, STATE 3, the radar results show small scale variations which co-align very well with the large scale variations in the $(\Delta N)^2$ power. When compared to the electron density profiles we find, particularly in the STATE 1 data, that these increases in $(\Delta N)^2$ power co-locate with decreases in electron density. With respect to the origin for the turbulence, we have found evidence in the STATE 1 data set for an outer scale with a vertical wave number of about 800 m. The turbulence strength seems to be organized by this large wavelength structure which suggests that the microscale waves are controlled by the properties of the larger structures. The latter may be driven by one of the several mechanisms which have been suggested by researchers. We anticipate that a more detailed study of these data will shed light upon the source for summer mesospheric turbulence.

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A-1

Electron Density Irregularities of the Polar Mesosphere - STATE Campaign

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M. C. KELLEY (Cornell University, Ithica, NY 14853)

During the STATE campaign three rockets were launched at Poker Flat, Alaska containing dc (Langmuir-type) probes to measure electron density irregularities with high spatial resolution. The rockets were launched at times when the MST radar showed intense regions of back scatter in the mesosphere. In each case when the electron density measurements are compared to the radar echo power as a function of altitude, large changes and strong gradients in the electron density are observed in the region of most intense backscatter. However, the electron density profiles show markedly different characteristics, particularly the STATE 3 peak scattering region, where a 'bite out' in the electron density profile of over 50% is observed between 85 and 86 km. From the measurements spectra of the spatial density fluctuations were derived from approximately 65 to 90 km for several height intervals with the smallest approximately 100 meters. In general, a fit to the power spectra between 1.0 to 80 Hz (approximately 500 to 5 meters) gives an index of about -5/3 as expected in an inertial subrange of homogeneous, isotropic turbulence. In the region of most intense backscatter, however, the power is up over the whole frequency range by almost 3 orders of magnitude. In addition, these spectra show a continuous steepening in the viscous subrange beyond $10^2$Hz (approximately 4.5 m to 0.5 m) giving a much higher spectral index. The electron density profiles and the power spectra from the three rocket flights are compared and discussed. Detailed utilization of these data to compare with the radar measurements and for understanding of mesospheric turbulence are contained in a companion paper.

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Some rough (sentence structure, etc.) comments to go with accompanying figures —

Jim

STATE 1

Viewgraph #1

This shows at the top the geometry of the MST radar beams--64$^{o}$ beam to northeast; 334$^{o}$ beam to northwest and the vertical beam at 90$^{o}$ at 0,0 coordinate. For Salvo 1 the Super Arcas carrying the DC probe for electron density structure measurement was fired along the path near the 334$^{o}$ beam as shown. Rocket altitudes are indicated. On bottom the signal to noise in dB is shown as a function of altitude for both antennas. The frequency is 50 mHz which is $\lambda$ = 6 meters so the coherent scatter is due to half the $\lambda$ or 3 meters.

Viewgraph #2

Here we superimpose the 334$^{o}$ beam S/N as a function of altitude on the DC probe measurements — Right where the structure in $N_e$ is the high S/N. The scatter above ~ 125 sec is due to spin effects.

Viewgraph #3

Here we show the DC probe results from previous slide in two intervals. To examine the data view power spectra analysis, we have to detrend the data and determining the zero order Ne is easier over short intervals. First the bottom data--note even to the eye the data is spin dominated (22 Hz). from 95 sec to about 103 sec (8 sec interval) but then one sees structure from 103 to 110 sec with spin superimposed. The power spectra for these two intervals ARE shown next.

Viewgraph #4

On the left side-the power spectrum from 95 - 103 sec. Note spin spike at about 22 hz (and 44 etc.). Note above about 10 Hz it is flat. Comparing with ~~to~~ the 103-110 sec data, we see again the spin spikes but now we also see a spectrum that gives an index close to the expected value for a one-dimensional spectrum of density fluctuations in an inertial subrange of homogeneous, isotropic turbulence (Kolmogorov--index about 1.7). Back to....

Viewgraph #2

The analysis of the data from 110.0 sec to about 114 sec. showed spectra as shown in Viewgraph 4 (previous) 103-110 sec. [Note--The structure is not apparent to the eye from 110-114 sec as it is from 103-110 sec but this is because the current scale is expanded for the 103-110 sec interval.] We analyzed the data from about 115 to 123 sec in 2 sec intervals shown on the next viewgraph.

Viewgraph #5

The most striking feature is increase in power of the two top spectra (a total of 4 sec interval where sharp gradients were obvious in viewgraph #2) and a clear index at the higher frequencies--the dispersive subrange. A line

fit to the data in the inertial subrange (1 to 70 hz) gives about -1.7 index while from about 200 hz to 300 hz gives an index near -3.6. Since the rocket velocity at this time was about 450 m/sec, the 150 hz region corresponds to about 3 meters spatially. We integrated the area under the curve from about $f_o$ - 20 Hz to $f_o$ + 20 Hz where $f_o$ is the frequency corresponding to 3 meters (about 150 hz). This is compared with the radar results in the next viewgraph. We integrated the power from spectra every 1/4 sec in the interval from 115 to 119 sec.

Viewgraph 6

The radar results (scale in dB on bottom) as x's are shown with rocket results. The correspondence is obvious. The probe shows more detail--more structure. The radar resolution was about 300 meters while the rocket was near 110 meters. There seems to be good evidence now that the radar is responding to $(\Delta N)^2$.

## STATE 3

### Viewgraph 1

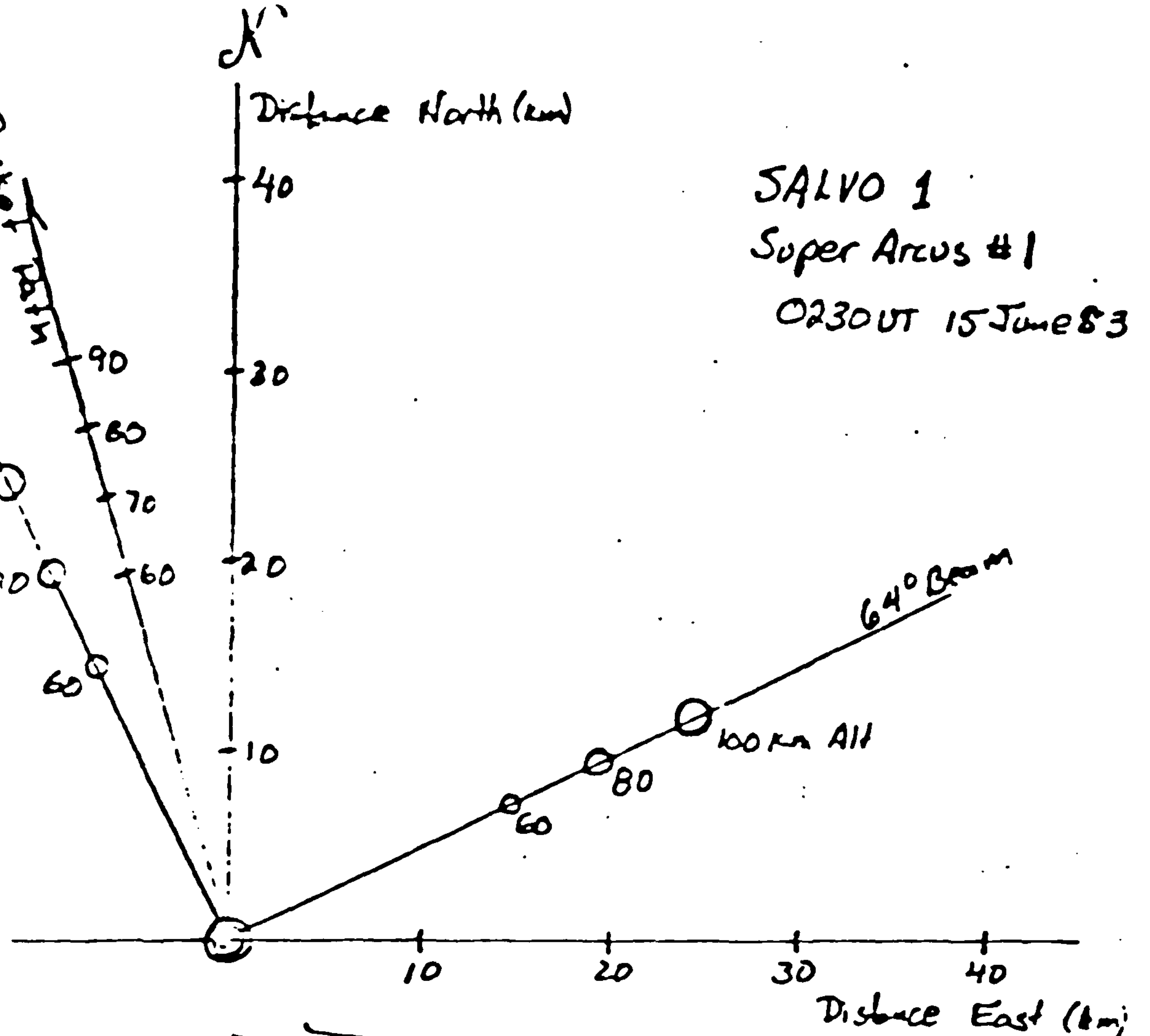
Like Viewgraph 1 in State 1 but note that the S/N from the two beams are quite different in power and in structure--i.e. spatially we have different structured regions.

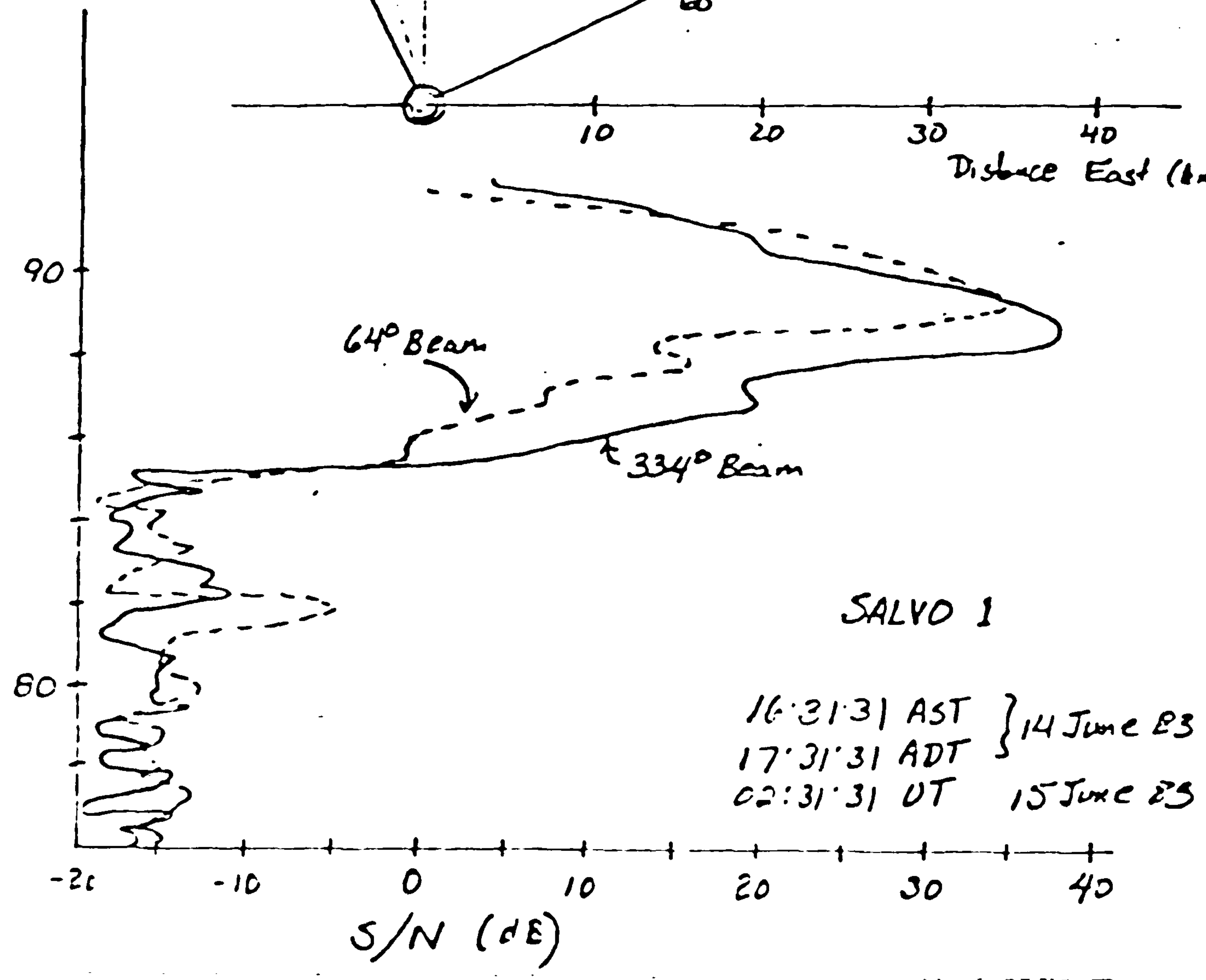
### Viewgraph 2.

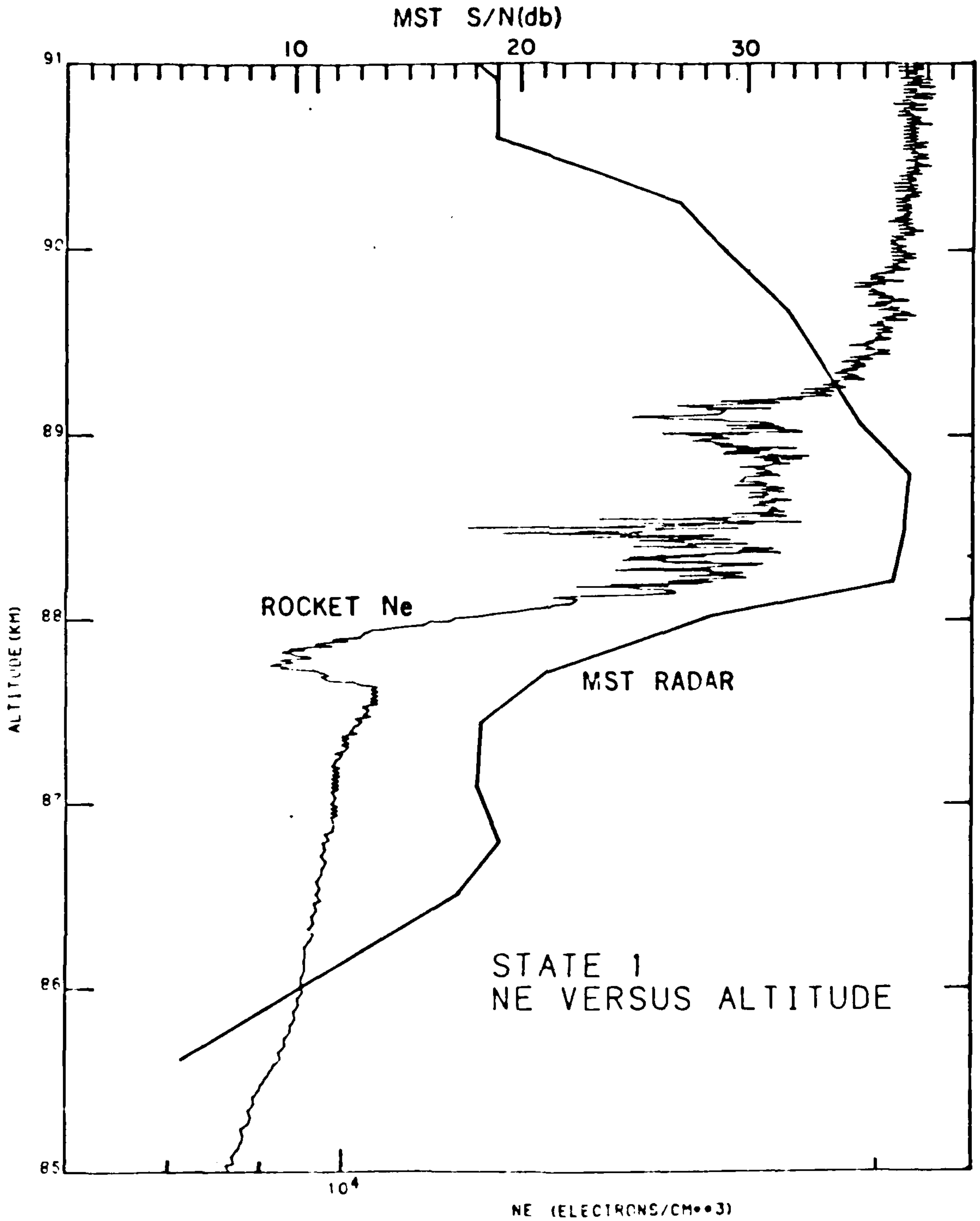
Like Viewgraph 2 of STATE 1. Note here that the increase in S/N of the radar is at the deep bite out in the Ne. What we have here is an electron density profile very similar to those reported for noctilucent clouds (also called polar mesosphere clouds). My personal opinion is that what we observe at Poker is the more sporadic--ragged edge-- of the more dense polar layer at the higher latitudes (within the polar cap) observed by UV measurements from satellites. In any case the Ne profile is quite striking--and analysis of these data similar to STATE 1 gives us the integrated power under the spectra near 3 meters every 1/4 sec. Shown in next viewgraph.

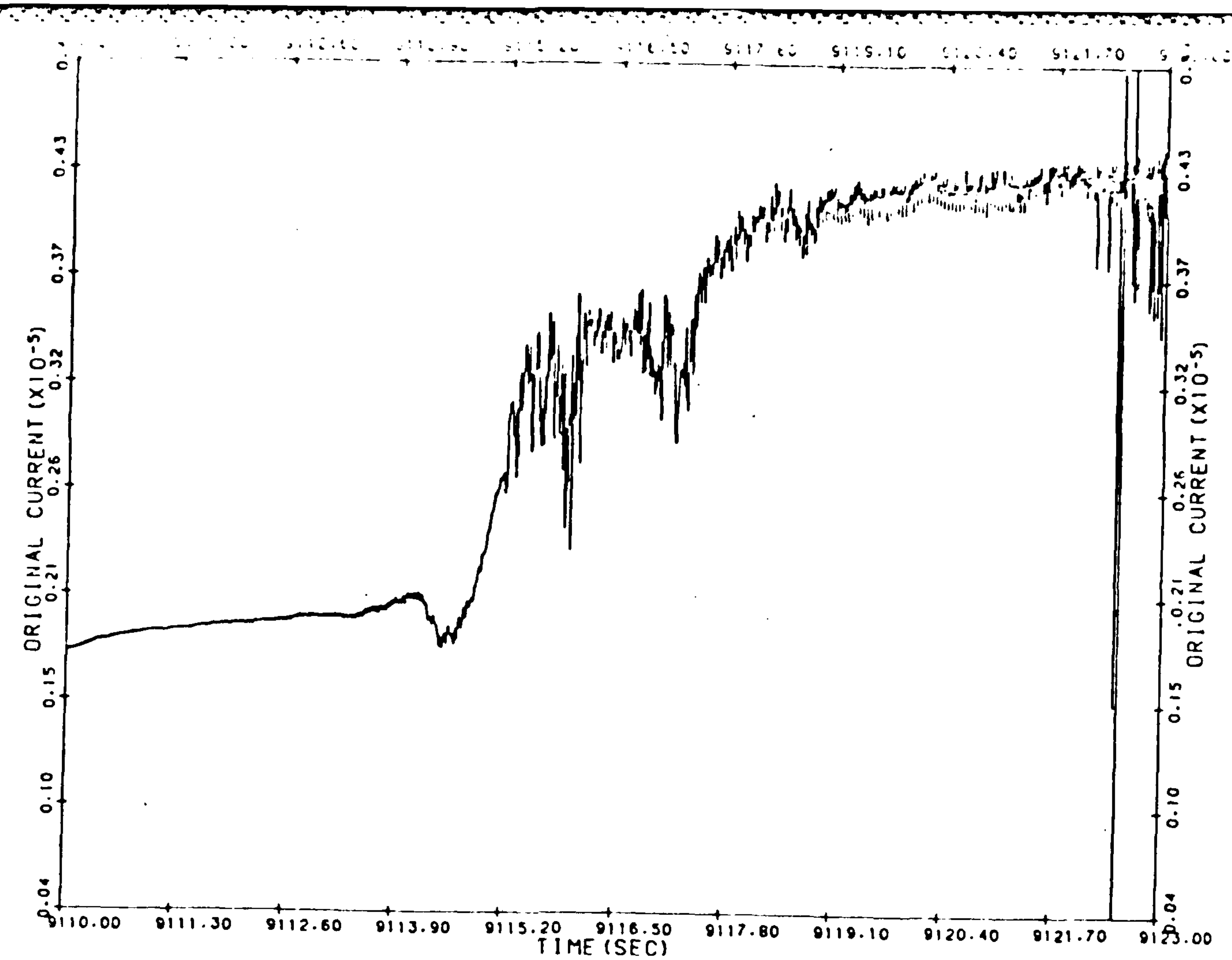
### Viewgraph 3.

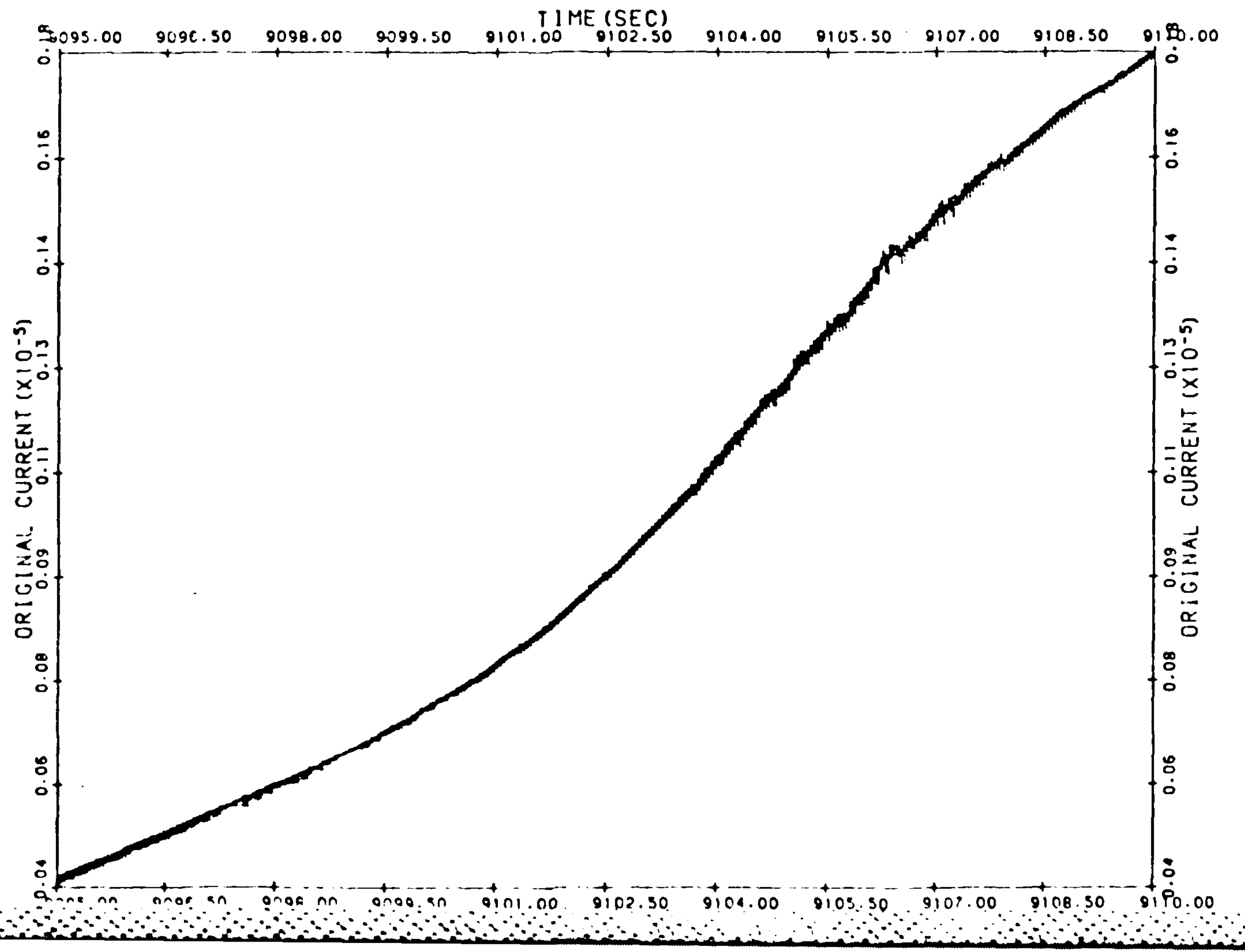
We again superimpose the radar results on top of the DC probe results. Again very nice comparison--but note also that here where the probe results show much sharper peaks than in STATE 1; the radar shows corresponding peaks. Remember in viewgraph 1 that the two beams gave quite different results--much spatial structure. This is why our proposed IR mapping experiment is important. We presume that at this altitude the Ne structure observed here is the same as the neutral structure (collision dominated). Therefore, IR emitters, e.g. $OH^{\ddagger}$, which peaks near 85 km should exhibit the same spatial structure.

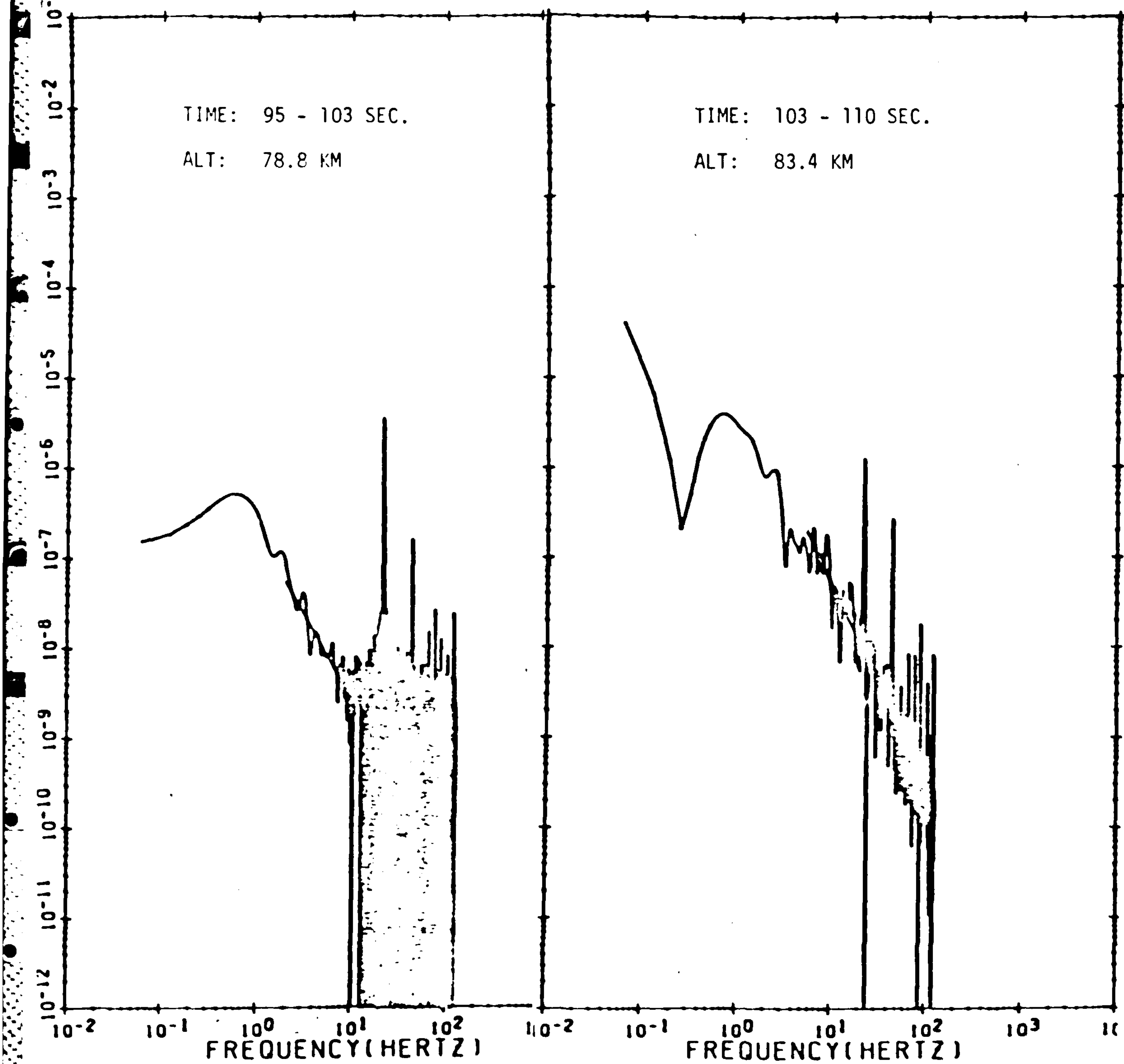

N
Distance North (km)
Rocket Path
334° Beam
SALVO 1
Super Arcus #1
0230UT 15 June 83
64° Beam
100 km Alt
Distance East (km)


64° Beam
334° Beam
SALVO 1
16:31:31 AST
17:31:31 ADT
14 June 83
02:31:31 UT 15 June 83
S/N (dB)

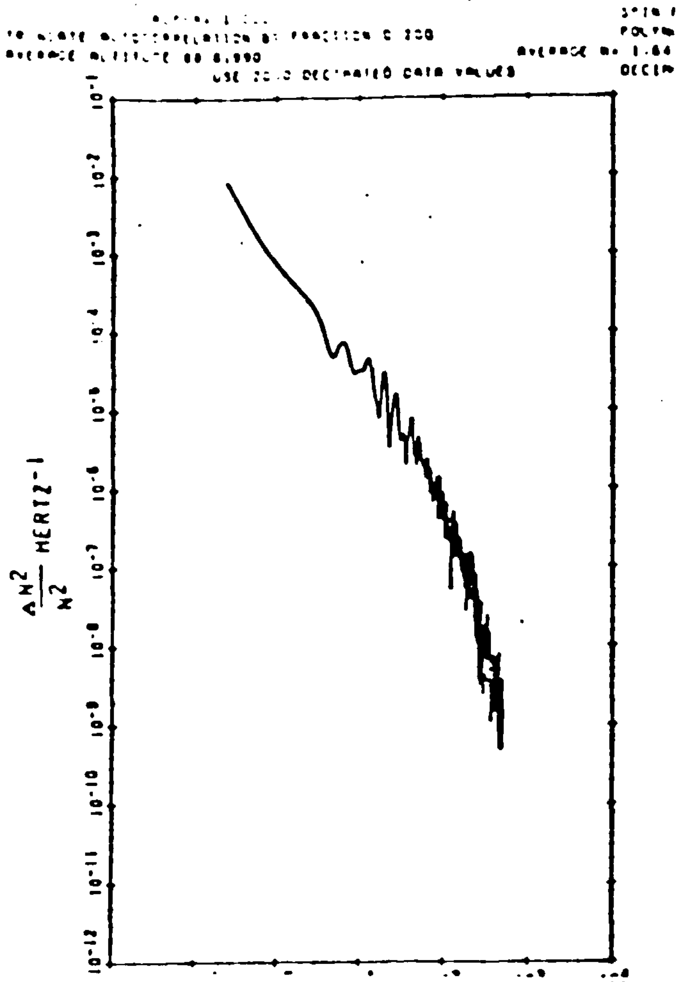

MST S/N(db)
10
20
30
91
90
89
88
87
86
85
ALTITUDE (KM)
ROCKET Ne
MST RADAR
STATE 1
NE VERSUS ALTITUDE
$10^4$
NE (ELECTRONS/CM**3)


ORIGINAL CURRENT (X10^-5)
TIME (SEC)
9110.00
9111.30
9112.60
9113.90
9115.20
9116.50
9117.80
9119.10
9120.40
9121.70
0.04
0.10
0.15
0.21
0.26
0.32
0.37
0.43

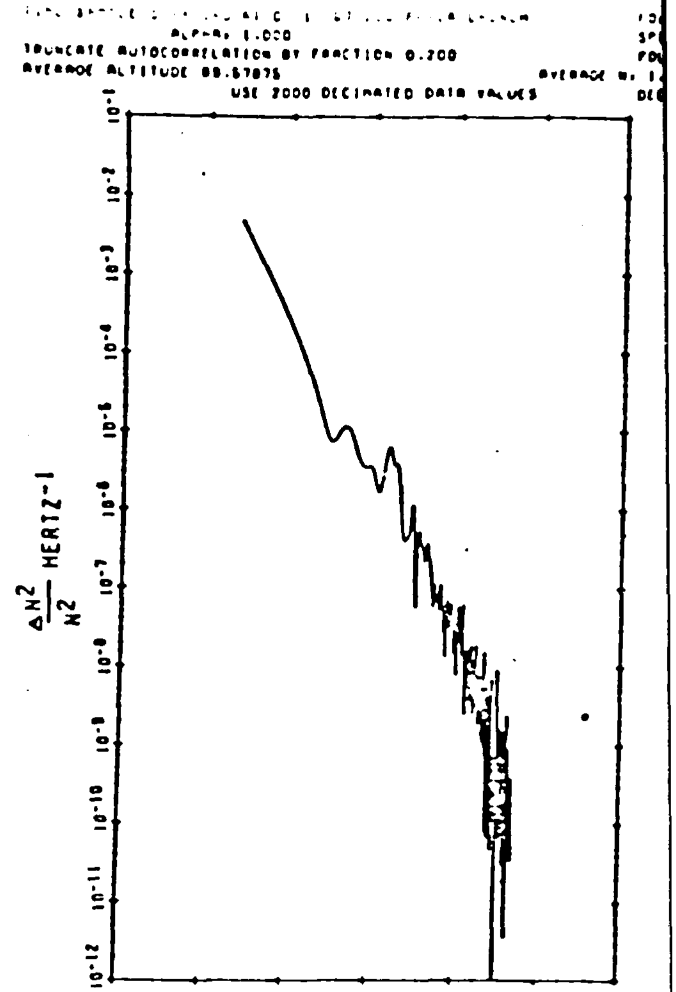

TIME (SEC)
ORIGINAL CURRENT (X10^-5)
9095.00
9101.00
9102.50
9104.00
9105.50
9107.00
9108.50
9110.00
0.04
0.06
0.08
0.09
0.11
0.13
0.14
0.16



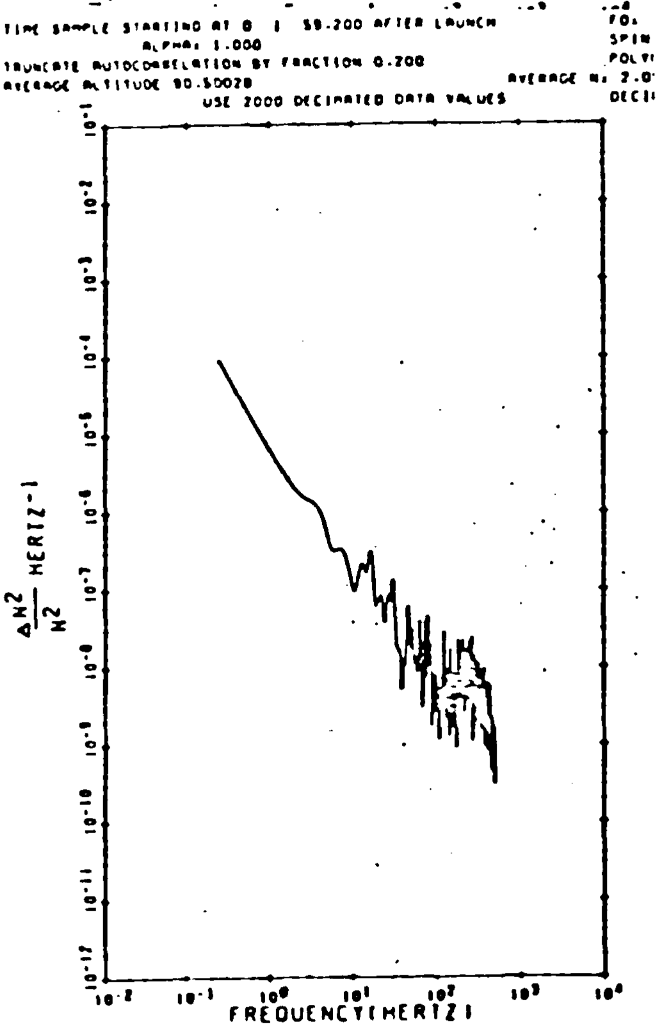
TIME: 95 - 103 SEC.
ALT: 78.8 KM
TIME: 103 - 110 SEC.
ALT: 83.4 KM
FREQUENCY(HERTZ)
FREQUENCY(HERTZ)



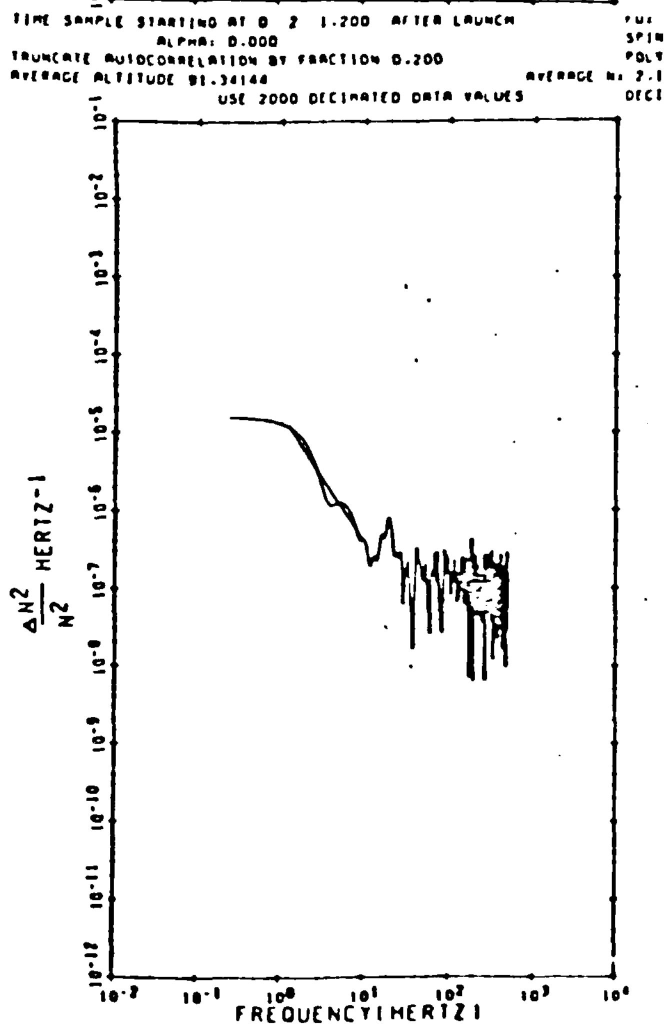
AVERAGE ALTITUDE 89.990
USE 2000 DECIMATED DATA VALUES
$\frac{\Delta N^2}{N^2}$ HERTZ$^{-1}$

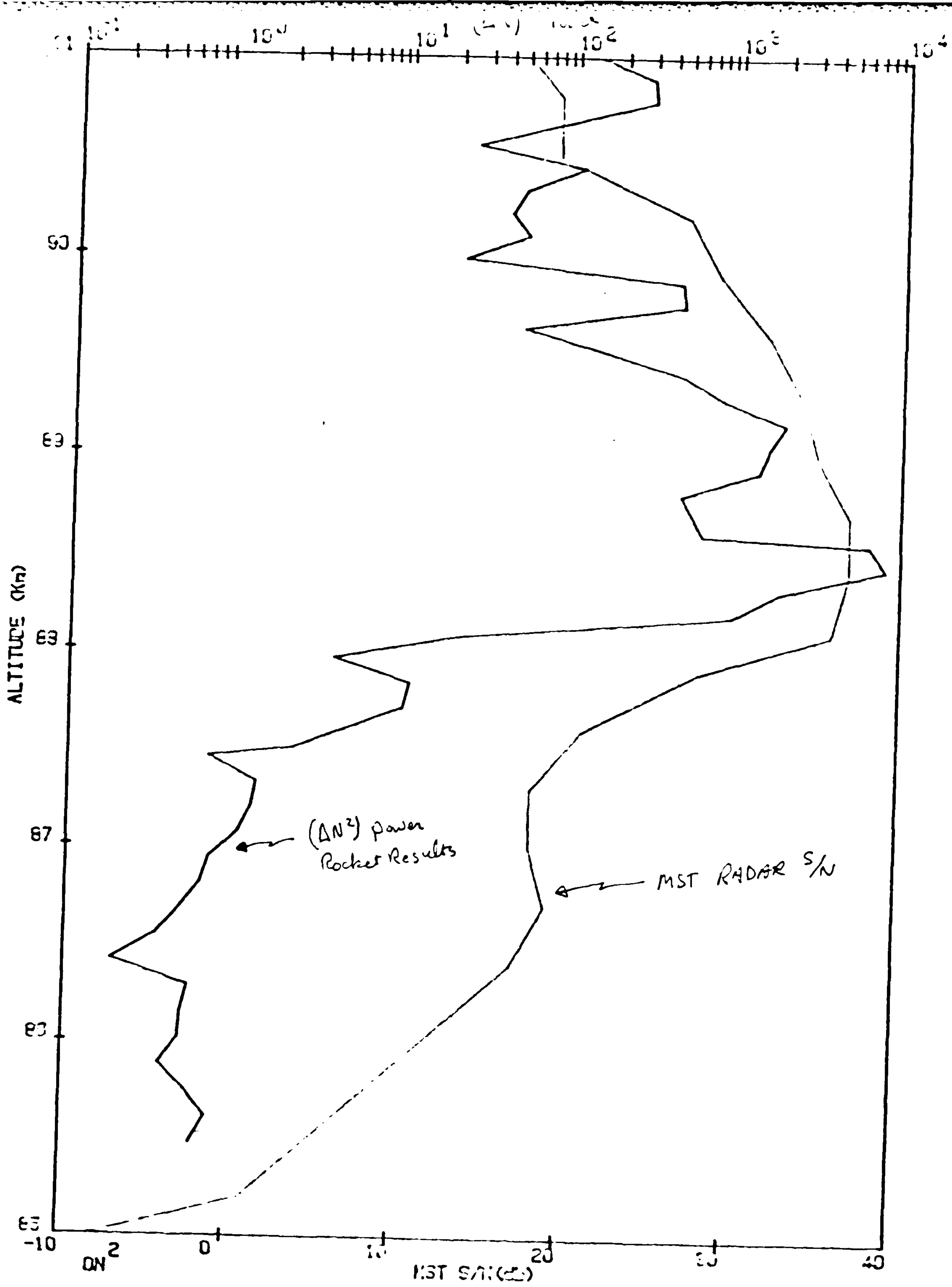
ALPHA: 1.000
TRUNCATE AUTOCORRELATION BY FRACTION 0.200
AVERAGE ALTITUDE 89.57875
USE 2000 DECIMATED DATA VALUES
$\frac{\Delta N^2}{N^2}$ HERTZ$^{-1}$

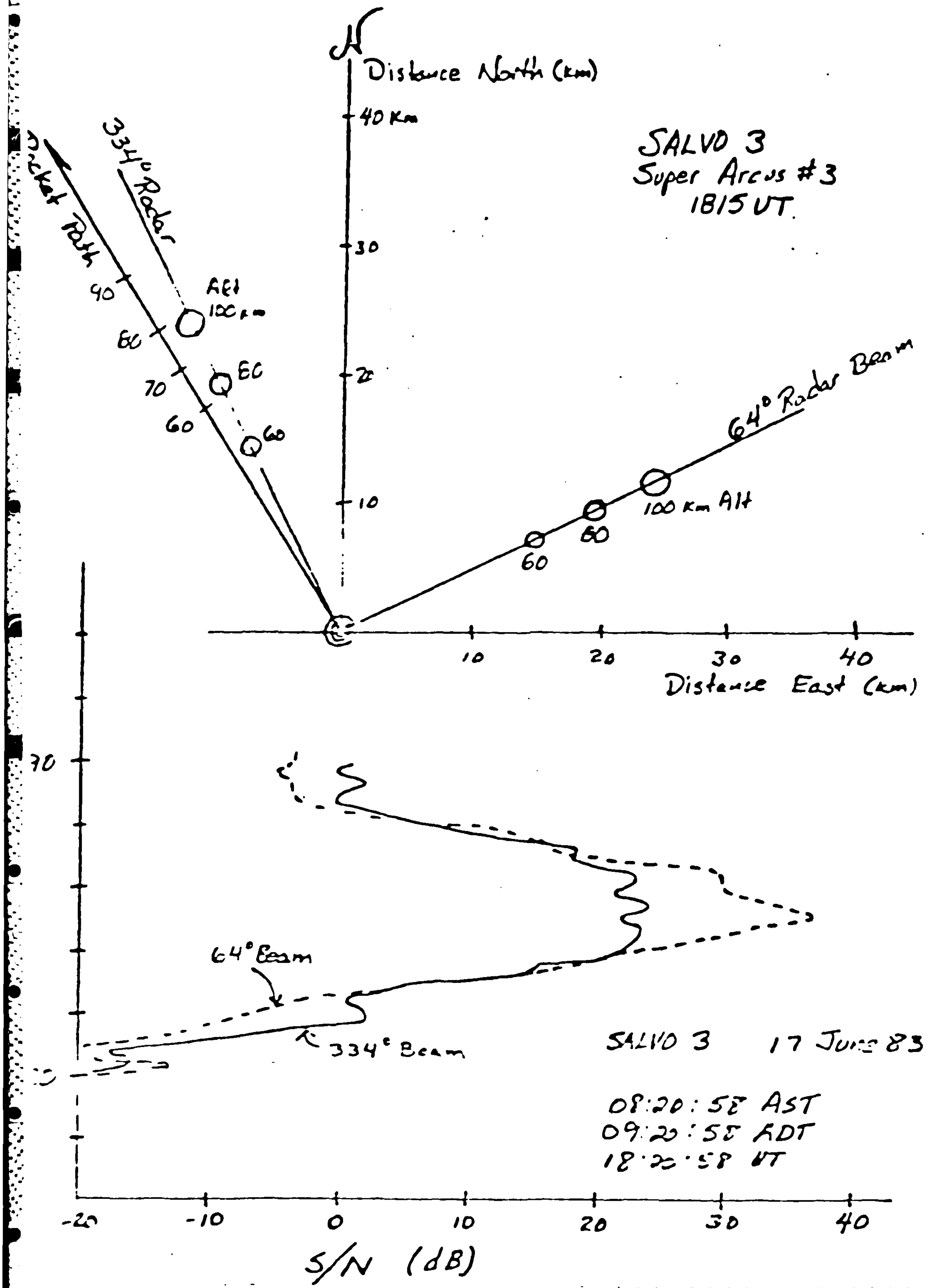



TIME SAMPLE STARTING AT 0 1 59.200 AFTER LAUNCH
ALPHA: 1.000
TRUNCATE AUTOCORRELATION BY FRACTION 0.200
AVERAGE ALTITUDE 90.50028
AVERAGE N: 2.0
USE 2000 DECIMATED DATA VALUES
$\frac{\Delta N^2}{N^2}$ HERTZ$^{-1}$
FREQUENCY(HERTZ)

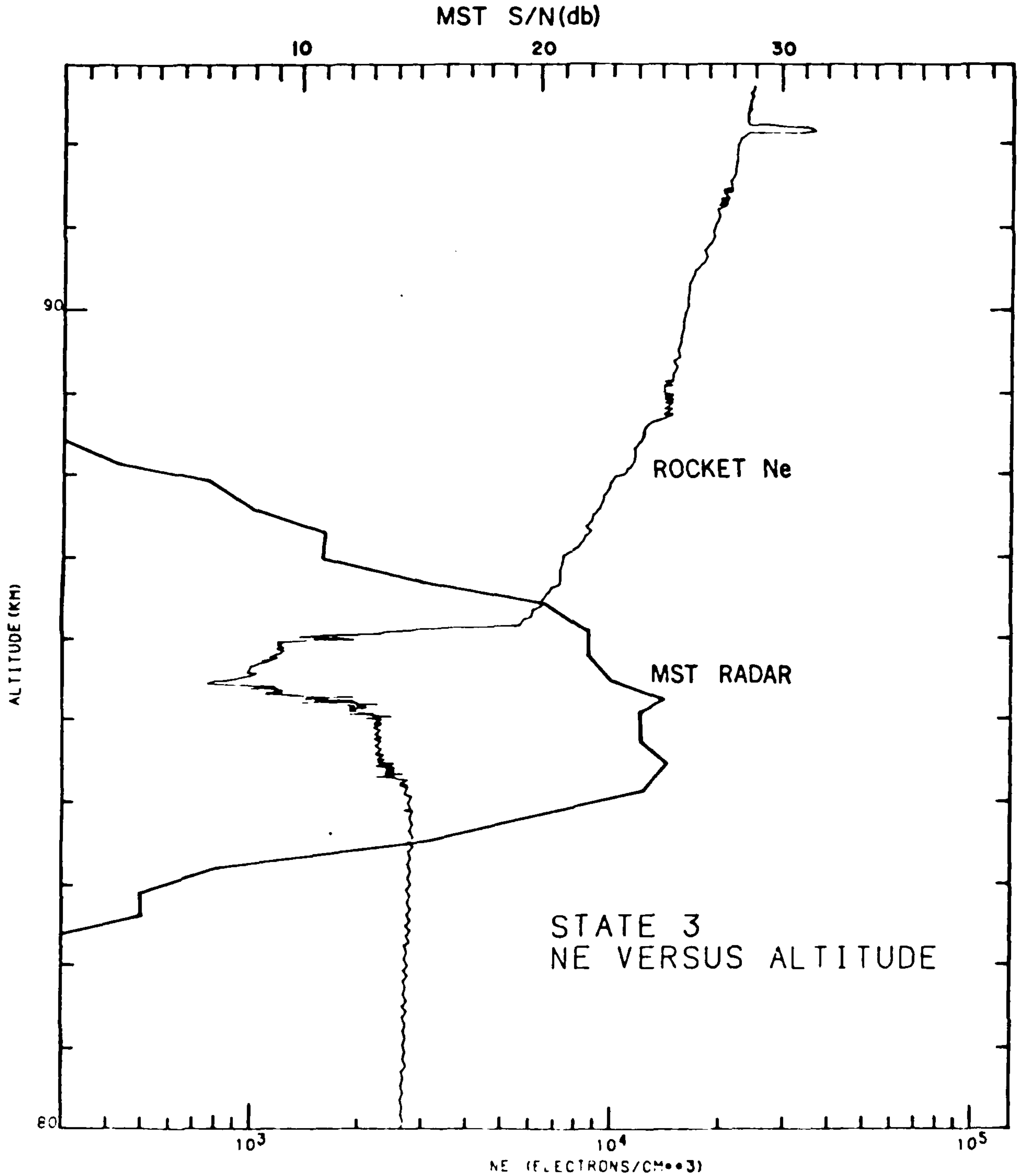



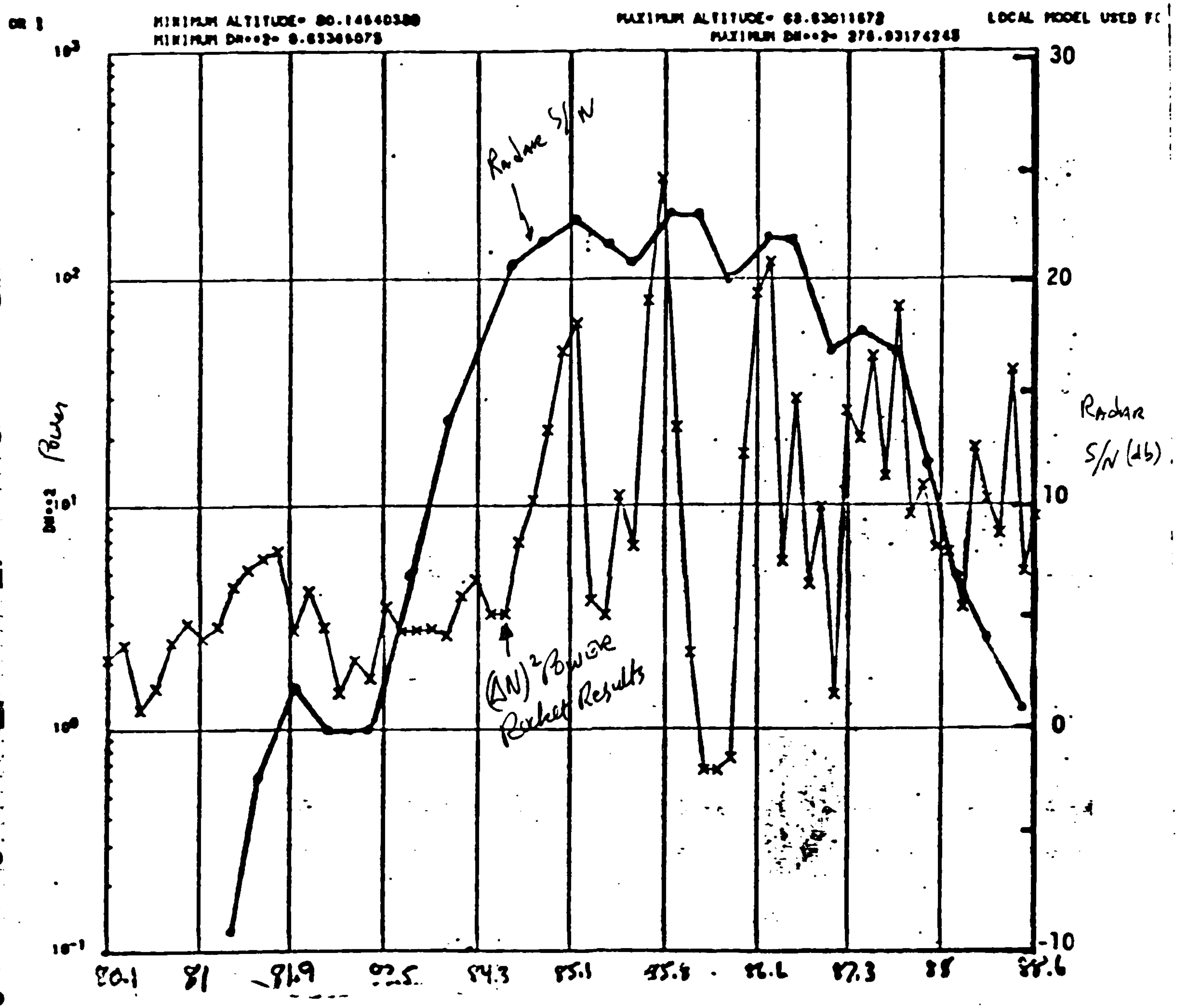
TIME SAMPLE STARTING AT 0 2 1.200 AFTER LAUNCH
ALPHA: 0.000
TRUNCATE AUTOCORRELATION BY FRACTION 0.200
AVERAGE ALTITUDE 91.34144
AVERAGE N: 2.1
USE 2000 DECIMATED DATA VALUES
$\frac{\Delta N^2}{N^2}$ HERTZ$^{-1}$
FREQUENCY(HERTZ)


ALTITUDE (Km)
90
87
-10
0
40
($\Delta N^2$) power
Rocket Results
MST RADAR S/N



SALVO 3
Super Arcus #3
1815 UT
Distance North (km)
40 Km
30
20
10
Rocket Path
334° Radar
Alt 100 km
80
60
90
70
64° Radar Beam
100 Km Alt
Distance East (km)
64° Beam
334° Beam
SALVO 3 17 June 83
08:20:58 AST
09:20:58 ADT
18:20:58 UT
-20
-10
0
10
20
30
40
S/N (dB)


MST S/N(db)
10
20
30
90
80
ALTITUDE (KM)
ROCKET Ne
MST RADAR
STATE 3
NE VERSUS ALTITUDE
$10^3$
$10^4$
$10^5$
NE (ELECTRONS/CM**3)



MINIMUM ALTITUDE= 80.14640380
MINIMUM DN**2= 0.65365075
MAXIMUM ALTITUDE= 88.63011672
MAXIMUM DN**2= 276.83174245
LOCAL MODEL USED FC
Radar S/N
(ΔN)² Power
Rocket Results
Power
DN**2
Radar S/N (db)
80.1
81
81.9
82.5
84.3
85.1
85.8
86.6
87.3
88
88.6

# INTRODUCTION

## A. MAP/WINE OBJECTIVES -- GENERAL

The major thrust of the Middle Atmosphere Project "Winter in Northern Europe" (MAP/WINE) is the investigation of strong temporal and spatial variabilities during winter in the middle atmosphere (Stratosphere and Mesosphere) at high latitudes. The variability can be interpreted, for the most part, as being due to an enhanced level of wave activity but the causes and effects are not well understood. To understand this complete and coordinated measurements are needed of structual parameters of the middle atmosphere (pressure, temperature) and the dynamical processes of global scales (planetary waves, tides), of mesoscales (gravity waves, jet streams), and small scales (turbulence). In particular, project MAP/WINE is directed toward a better understanding of:

- the interaction of planetary waves of tropospheric origin with the mean flow in the stratosphere and mesosphere,
- the temporal and spatial development of sudden stratospheric warmings including the pre-warming conditions and the trigger mechanism for the warming,
- the temporal and spatial development of mesospheric cooling events in conjunction with stratospheric warmings,
- the vertical and horizontal transport of minor constituents like trace gases, excited species, and charged particles,
- the effects on the chemistry of neutral and charged species of the large temperature changes occurring during stratospheric warmings and mesospheric coolings.
- sources of turbulent energy in the mesosphere and turbopause region,
- the temporal and spatial development of turbulent layers, and
- the contributions of dynamical processes to the heating and cooling of the mesospheric and turbopause region.

B. MAP OBJECTIVES -- UTAH STATE UNIVERSITY

The proposed Utah State University experiment supports most of the MAP objectives directly by providing measurements of structure in two prime minor species, atomic oxygen and hydroxyl, and a related emission from an excited species of oxygen, $O_2{}^1\Delta_g$. Atomic oxygen in addition to being the most important species controlling the chemistry of the mesosphere has shown strong evidence of being highly structured [Dickinson et al., 1980, Howlett, et al., 1980]. The OH emission is the strongest infrared emitter in the mesosphere and has been observed to have variations and wave-like structure [Peterson, Kieffaber, 1973; Baker, 1978]. The cause of these structures has been suggested to be gravity waves [Tuan, Hedinger, Silverman and Okuda, 1979] phenomenon important to the objectives of MAP/WINE. The concentration of $O_2{}^1\Delta_g$ is important to atmospheric reactions involving the important minor constituents O, OH, and $O_3$.

## APPROACH

A. MAP/WINE -- GENERAL

Von Zahn, 1982, gives a complete description of the MAP/WINE Project and its status and this is included as Appendix A of this proposal. Briefly, however, the project will center on the study of the middle atmosphere over the full winter season of 1983/84. A coordinated and international study will be performed of the structure, motions, and composition of the middle atmosphere between about $50^o$ and $70^o$ northern latitudes. MST radars, LIDAR sounders, EISCAT radar and optical amd radio monitoring experiments (interferometers, photometers, etc.) will measure the small scale and mesoscale processes at selected sites on an almost continuing basis. Meteorological satellite data (Solar Mesosphere Explorer, NOAA-E/F, DMSP 5D, Dynamic Explorer) will provide important information on global scale processes. Special high altitude radiodondes, meteorological rockets, meteorwind radars, and sounding rockets will provide the additional and vital data not routinely available from WMO observations or remote sensing satellite experiments.

B. MAP/WINE -- UTAH STATE UNIVERSITY

To provide the specified measurements it is proposed to fly a resonance lamp system for atomic oxygen and a dual channel infrared radiometer for measurement of emissions from OH around 2 μm and $O_2\,{}^1\Delta_g$ at 1.27 μm aboard the MI Sergeant rocket payload to be flown from ESRANGE (Kiruna) during disturbed conditions. In addition to providing these critical measurements, this flight will provide a valuable opportunity to compare results of measurements of atomic oxygen from the USU resonance lamp with those derived from the infrared measurements of the spectrometer from the University of Wuppertal which is the prime instrument aboard the MI payload.

Both of the Utah State University instruments are flight proven and have been successfully utilized in many measurement programs including the highly successful Energy Budget Campaign and the United States ICECAP Program. From preliminary investigations it appears that these instruments could be incorporated into the MI payload with only minor modifications.

The experimental approach for the ground measurements will be to use a wide angle Michelson interferometer spectrometer to obtain spectra in the λ0.8 to 1.7 μm range which includes airglow bands of hydroxyl and molecular oxygen, auroral bands of both neutral and ionized molecular nitrogen, and auroral atomic nitrogen and oxygen lines. This is the experiment which was very successfully operated during the Energy Budget Campaign (Baker et al., 1983). The interferometer is operated with a resolving power of 5000 at 1.0 μm and a temporal resolution of 40 seconds. An NESR of $4\times10^{-14}$ watts-cm$^{-2}$sr$^{-1}$/cm$^{-1}$ at 1.4 μm is achieved through the use of large aperture optics, oblique ray compensation, an electromagnetic drive, a gas bearing and a liquid-nitrogen cooled germanium detector. In addition, coaligned photometer/radiometers will be operated at λ3914A, 1.27 μm and 1.7 μm to provide continuous absolute measurements of emission bands of $N_2$, $N_2^+$, $O_2$ and OH. An imaging system is coaligned for OH structure observations. Rotational temperatures are computed from the observed OH band structure.

## EXPERIMENTS

Table No. 1 summarizes the proposed measurements to be made by Utah State University as part of the MAP/WINE Campaign.

### TABLE No. 1

Rocket

| Measurements | Instrument | Wavelength |
|---|---|---|
| Atomic Oxygen Density | Resonance Lamp | 1304Å |
| $O_2\,{}^1\Delta_g$ Emission | IR Two Channel Radiometer | 1.27 μm |
| OH Emissions | IR Two Channel Radiometer | |

Ground Based

| Measurements | Instrument | Wavelength |
|---|---|---|
| Near IR Spectra | Interferometer | 0.85 - 1.7 μm |
| $O_2\,{}^1\Delta_g$ and OH Emissions | Radiometer/Photometer | 1.27 μm and 1.31 μm |
| $N_2^+$ and OI Emissions | Scanning Photometer | 3914, 5577, 6300λ |
| OH Structure | Imaging System | |

References

Baker, D.J., "Studies of Atmospheric Infrared Emissions, AFGL-TR-78-0251, Utah State University, Logan, Utah , January 1, 1978.

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Figure 1 and 2. These show the atomic oxygen concentration measured by the resonance lamp technique on board the MI payload launched on 10 February 1984. The results are preliminary because we don't have a trajectory for this rocket. The ascent and descent match pretty well from 80 to 105 km but from 105 to peak altitude the ascent is about a factor of two higher.

Figure 3. We compare the MAP/WINE ascent data with the only other [O] measurement we have made at night under non-auroral conditions. As you can see the agreement is quite good.

Figure 4. If we compare these results to the CIRA 1972 reference, we are about a factor of five lower at all altitudes from 100 km to 180 km i.e., the shape is identical but shifted. Below 100 km we show the same $10^{11} cm^{-3}$ concentration to 88 km while the reference model drops off by a factor of about 3 to 4.

Figure 5 and 6. These show the OH radiometer radiance for ascent and descent for 1.55 μm. The $O_2(^1\Delta)$ radiance was too low for us to detect so we only have a threshold number, i.e. the $O_2(^1\Delta)$ radiance that night was at least below our threshold. Note the effects of the rocket spin. You remember I deliberately offset the radiometer from the vertical by $45^o$ to see if we could detect any spatial structure. Note on ascent the higher radiance changes compared to descent in the 60-75 km region. We need aspect data to examine this. Note how well the ascent and descent data agree otherwise. We should have no problem deriving volume emission rates.

Figure 7. This figure shows the OH Meinel spectra in the 1.5 μm region illustrating the $P_1(K^{11})$ and $P_2(K^{11})$ lines used in the "Boltzmann Plot". (Spectra are not apodized or interpolated and have not been instrument corrected). Note that these data are for the time near launch. We should also have $O_2(^1\Delta)$ data from the interferometer.

Figure 8. The "Boltzmann Plot" for Figure 7 data--shown just to indicate how we use spectra to get Rot. temp. of course, the results are very preliminary--we will use the $P_2(K^{11})$ data and several other measurements to arrive at a more accurate Rot. Temp.

Figure 9. Shows the NIR radiometer data from ground measurement that we have available to go along with our rocket data.

Figure 10. Gives a summary (catalogue) of our operational times during MAP/WINE. These data will be processed for use with your ground observations to study temperature structure.

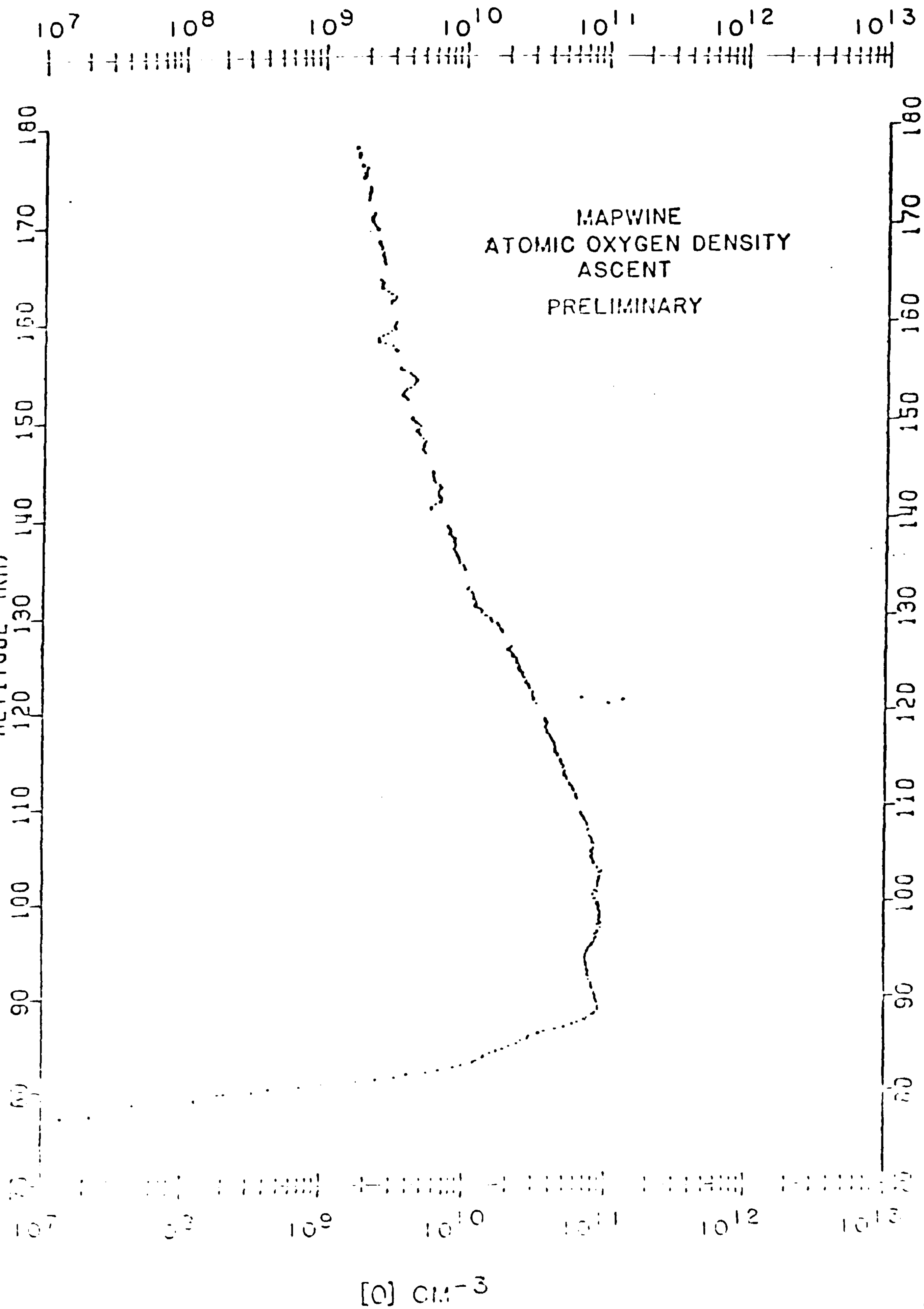
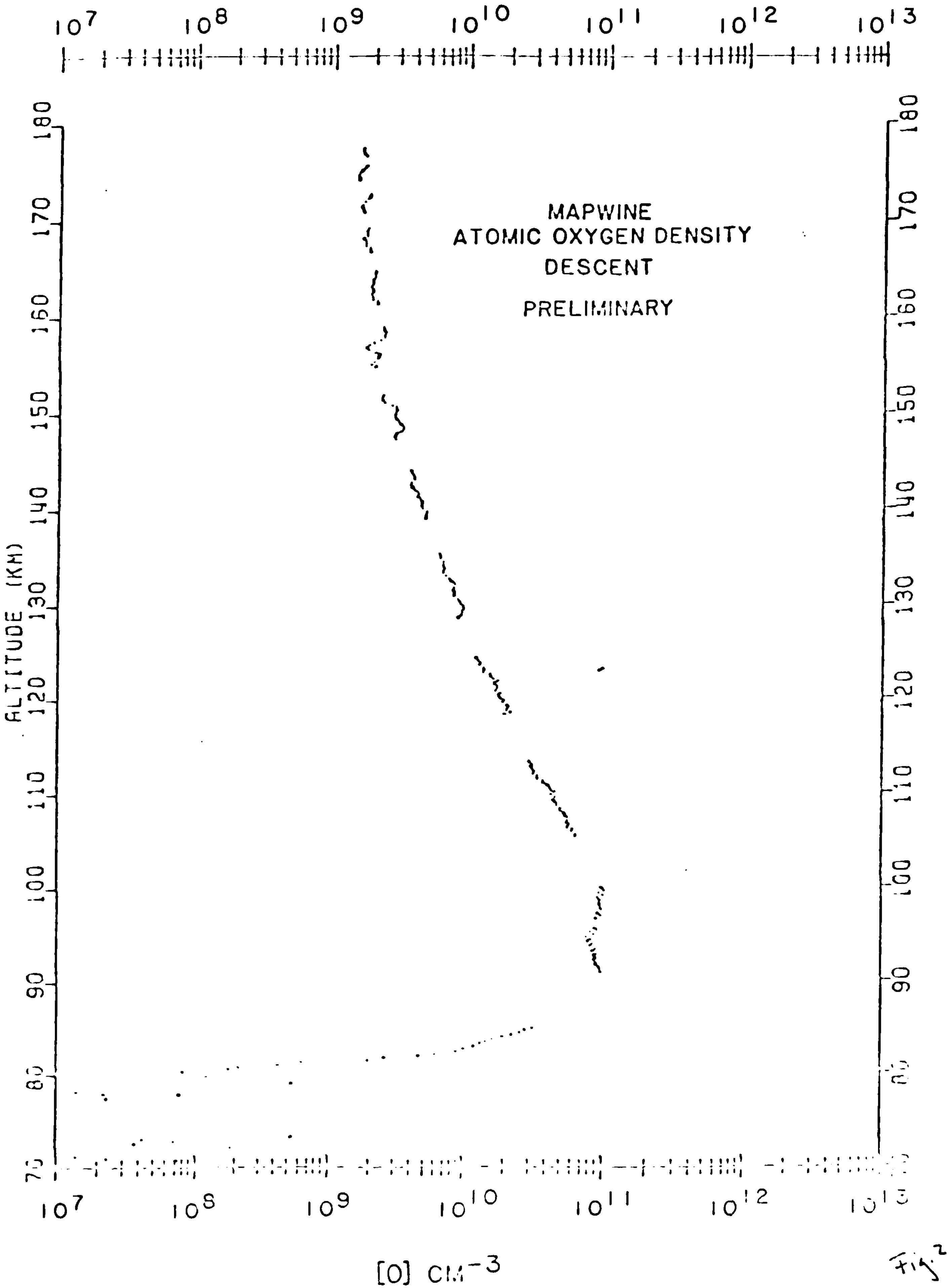
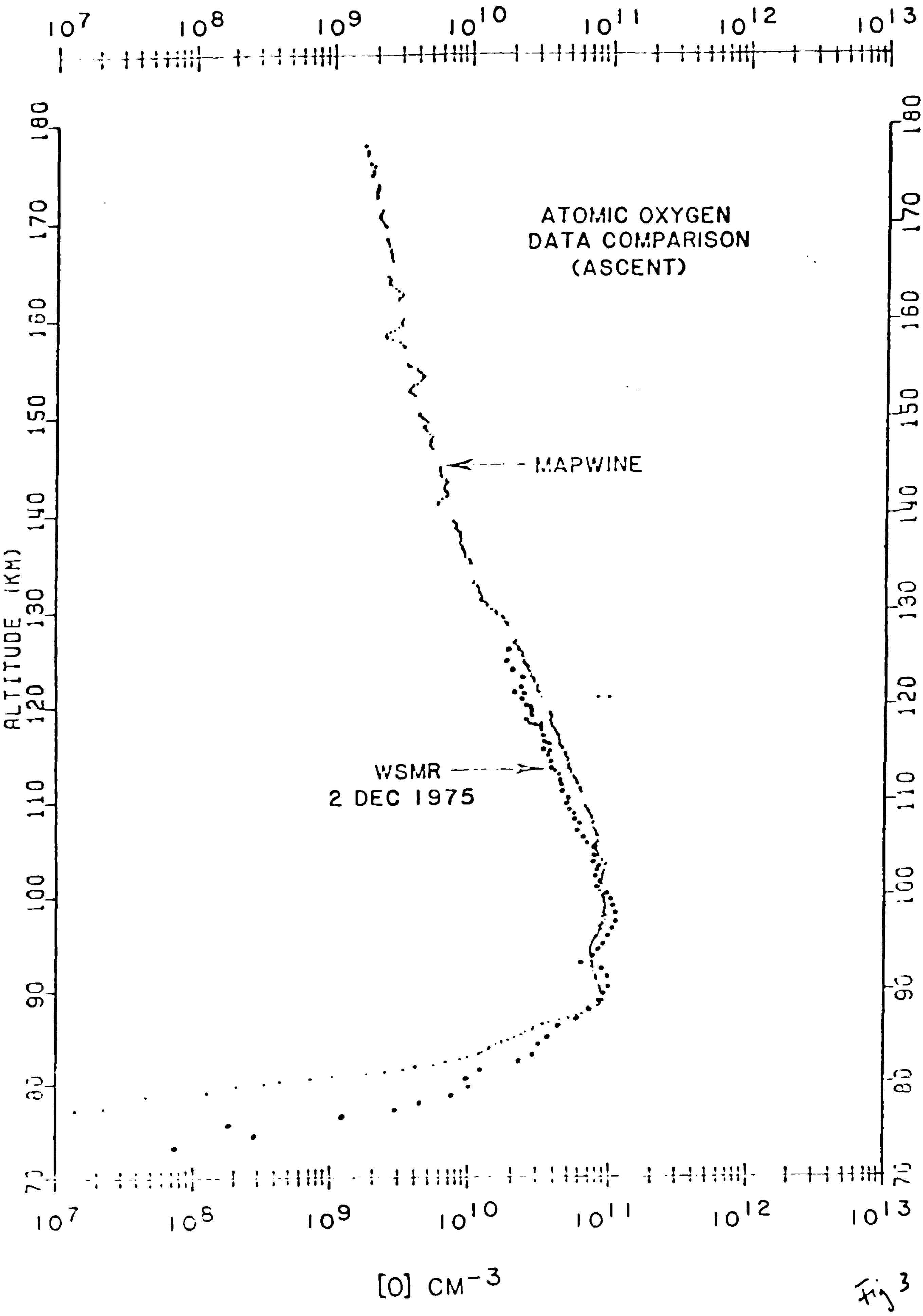

MAPWINE
ATOMIC OXYGEN DENSITY
ASCENT
PRELIMINARY
ALTITUDE (KM)
[O] CM$^{-3}$
$10^7$ $10^8$ $10^9$ $10^{10}$ $10^{11}$ $10^{12}$ $10^{13}$
90 100 110 120 130 140 150 160 170 180

Fig 1.


MAPWINE
ATOMIC OXYGEN DENSITY
DESCENT
PRELIMINARY
ALTITUDE (KM)
[O] CM$^{-3}$
Fig. 2


ATOMIC OXYGEN
DATA COMPARISON
(ASCENT)
MAPWINE
WSMR
2 DEC 1975
ALTITUDE (KM)
[O] CM$^{-3}$
Fig 3

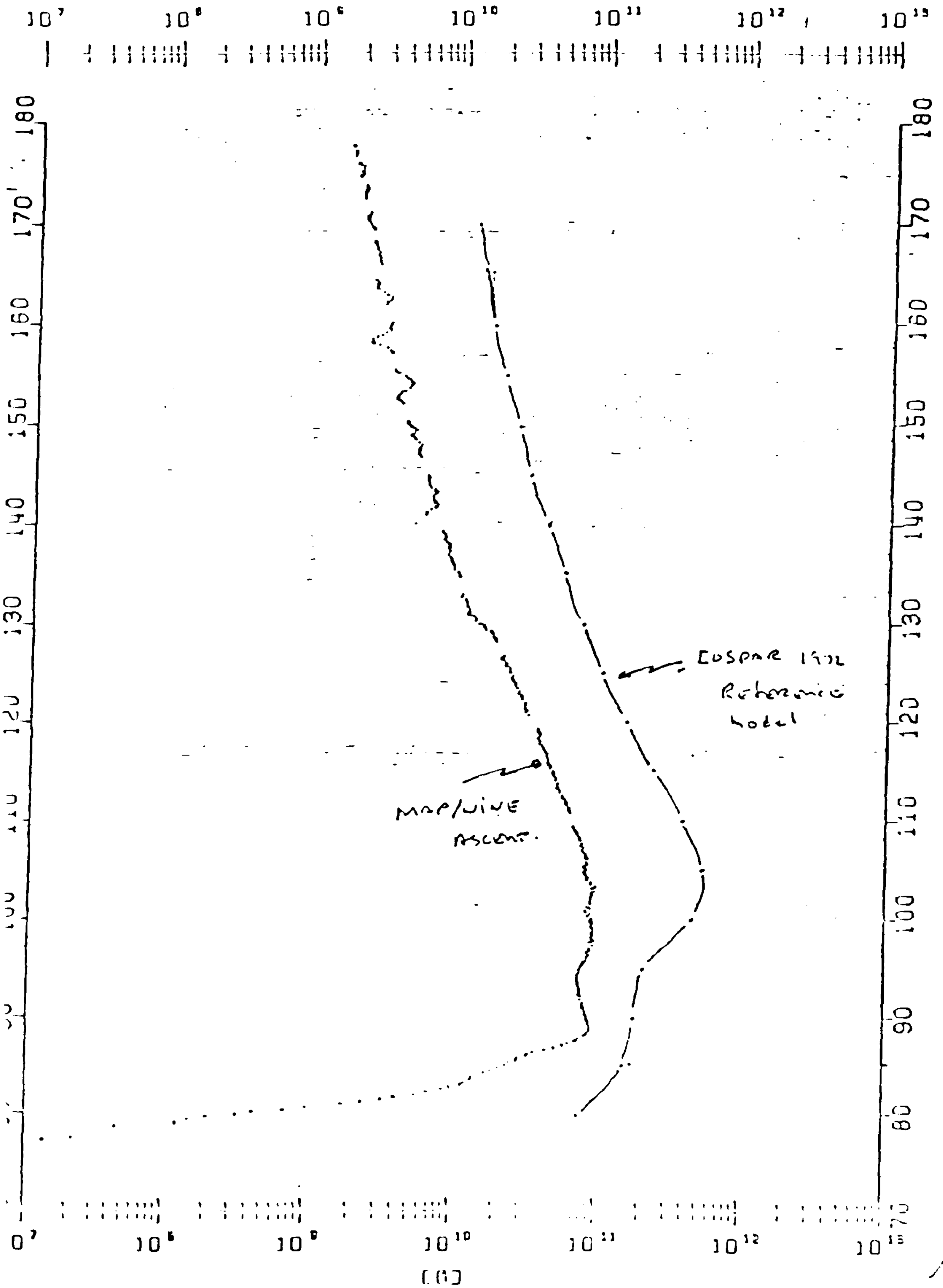
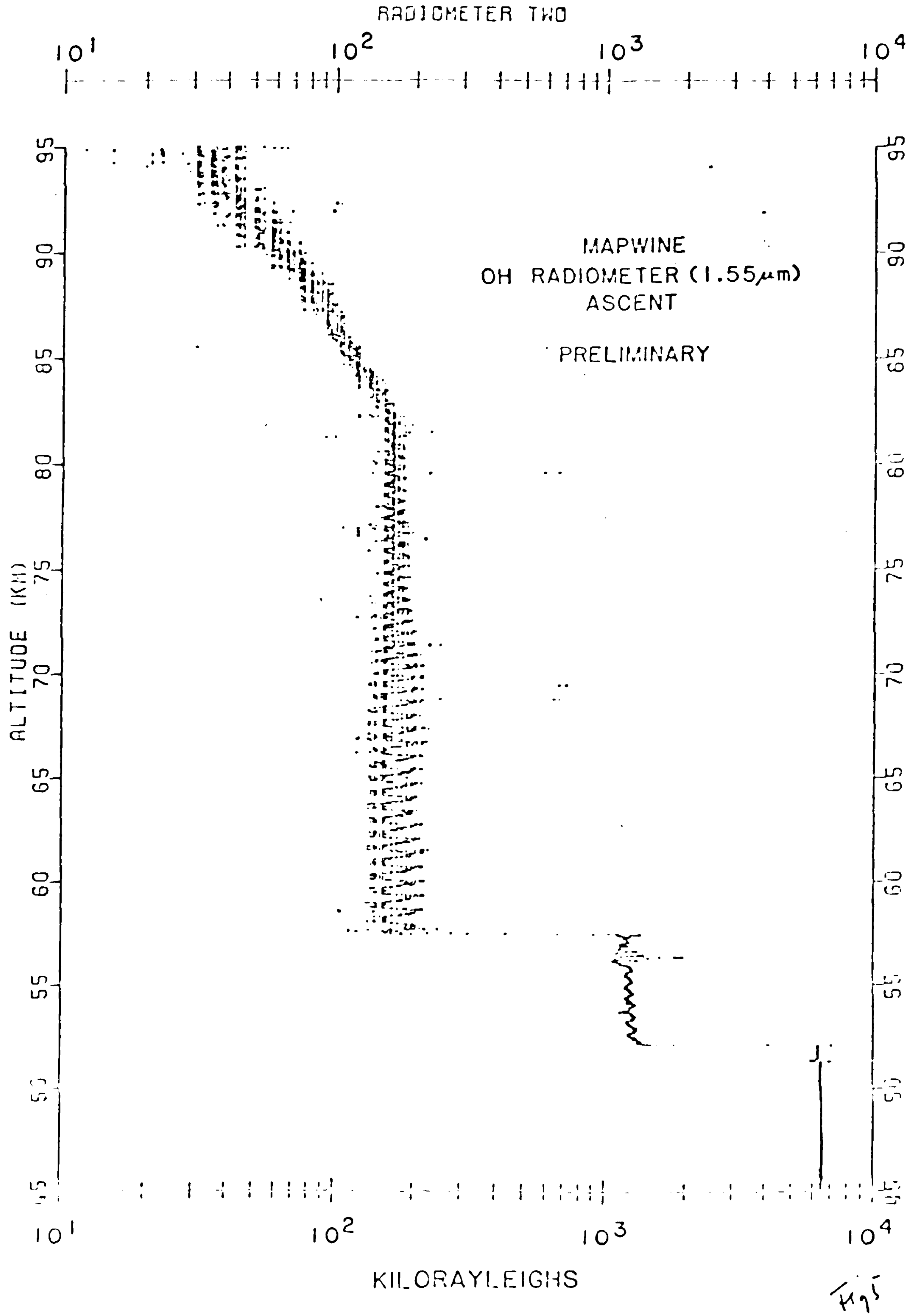
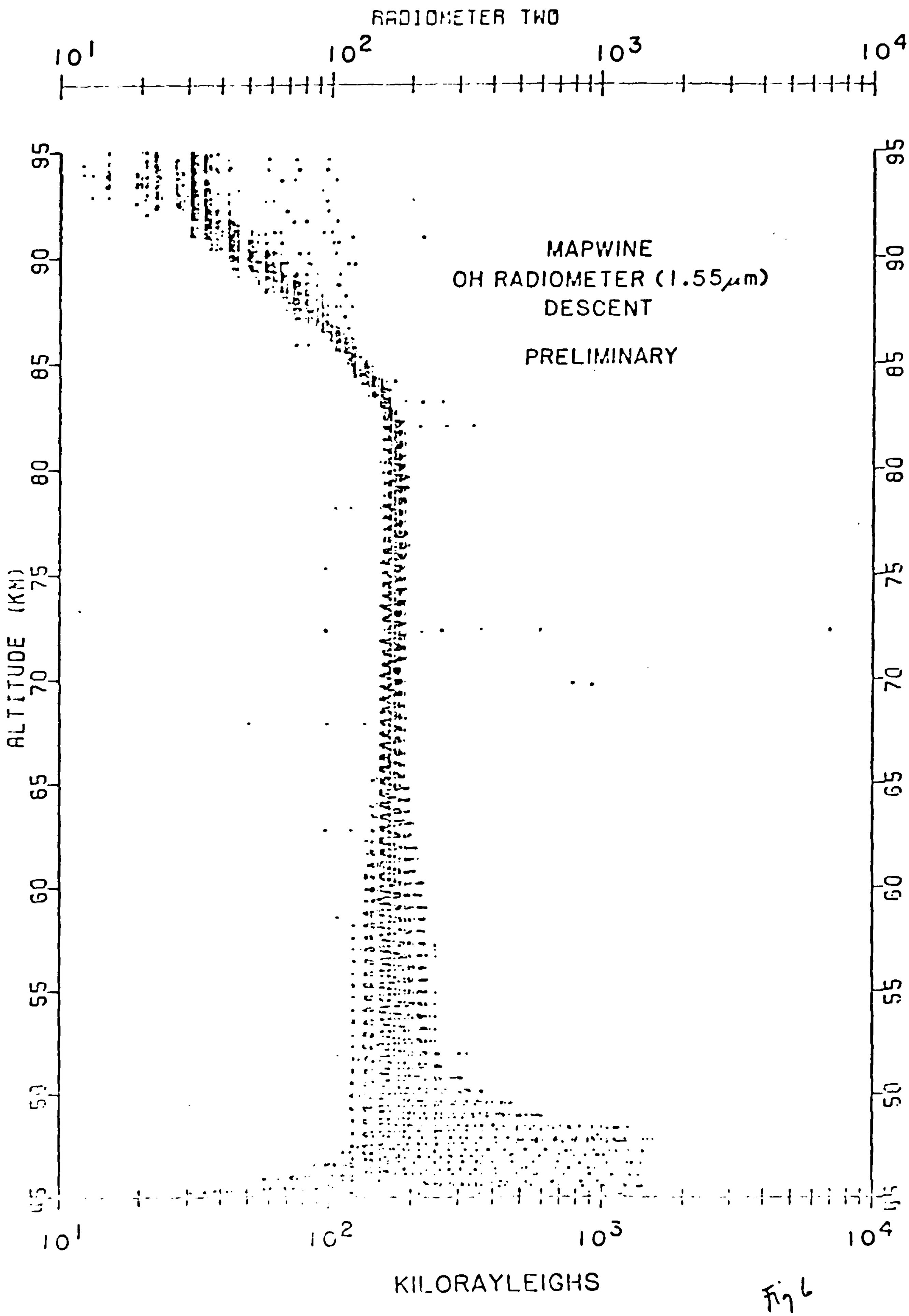



Fig. 4

MAP/WINE
Ascent Prelim...


RADIOMETER TWO
MAPWINE
OH RADIOMETER (1.55μm)
ASCENT
PRELIMINARY
ALTITUDE (KM)
KILORAYLEIGHS
Fig 5


RADIOMETER TWO
MAPWINE
OH RADIOMETER (1.55$\mu$m)
DESCENT
PRELIMINARY
ALTITUDE (KM)
KILORAYLEIGHS
Fig 6

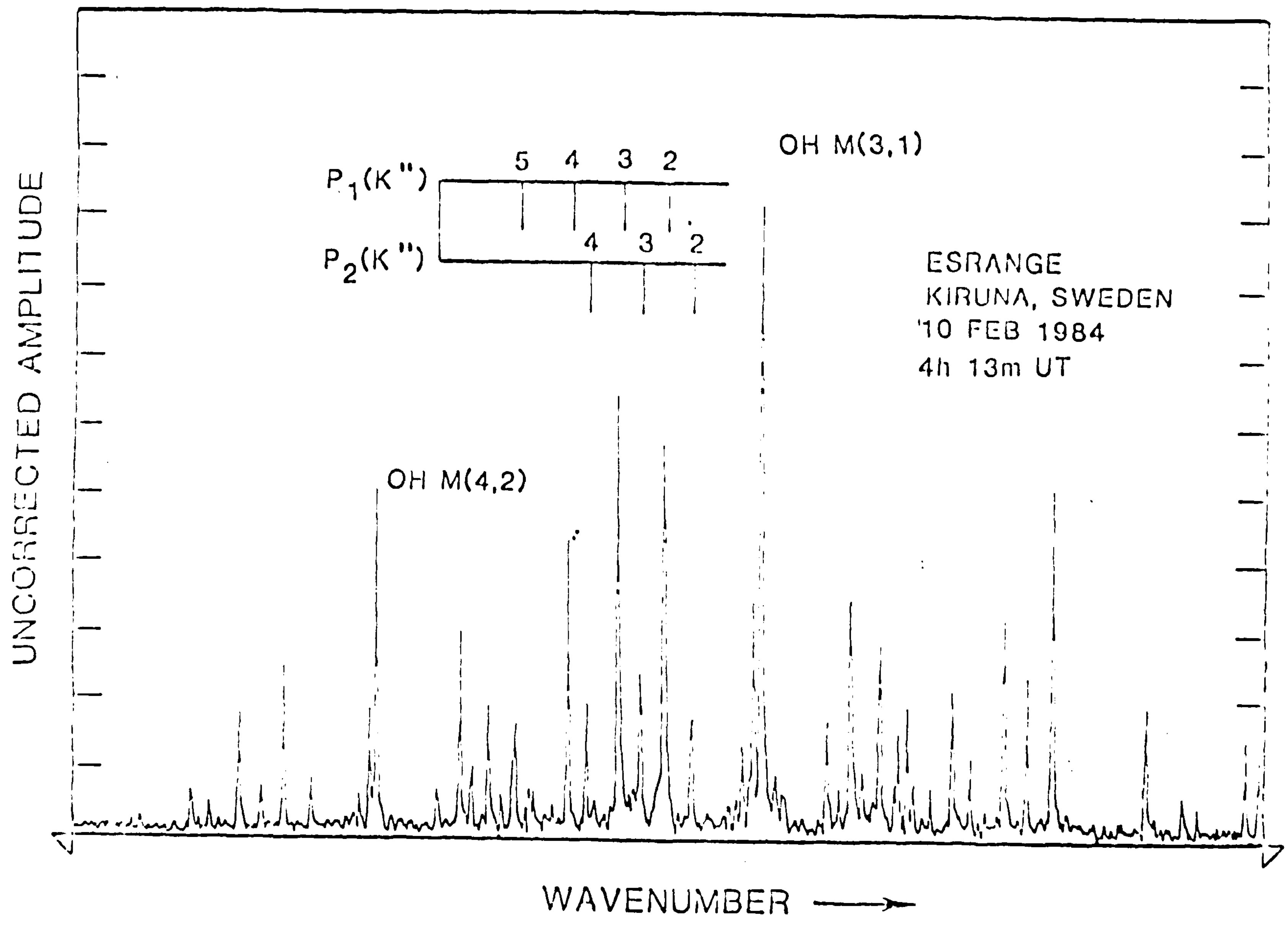
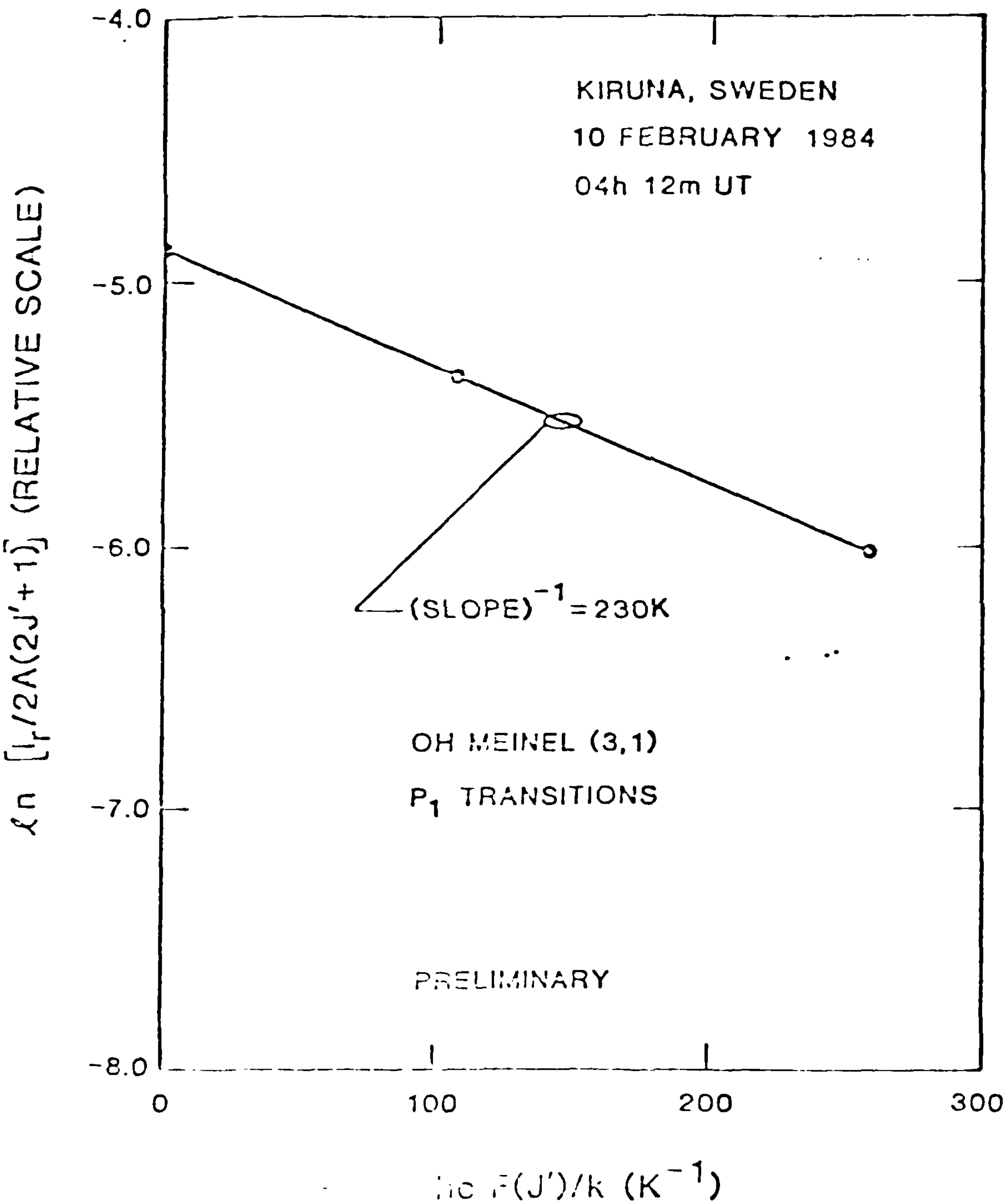

UNCORRECTED AMPLITUDE
$P_1(K'')$
5 4 3 2
$P_2(K'')$
4 3 2
OH M(3,1)
OH M(4,2)
ESRANGE
KIRUNA, SWEDEN
10 FEB 1984
4h 13m UT
WAVENUMBER

Fig 2



KIRUNA, SWEDEN
10 FEBRUARY 1984
04h 12m UT
(SLOPE)$^{-1}$ = 230K
OH MEINEL (3,1)
$P_1$ TRANSITIONS
PRELIMINARY
-4.0
-5.0
-6.0
-7.0
-8.0
0
100
200
300
$\ell n\ [I_r/2A(2J'+1)]$ (RELATIVE SCALE)
hc F(J')/k ($K^{-1}$)


Fig 8

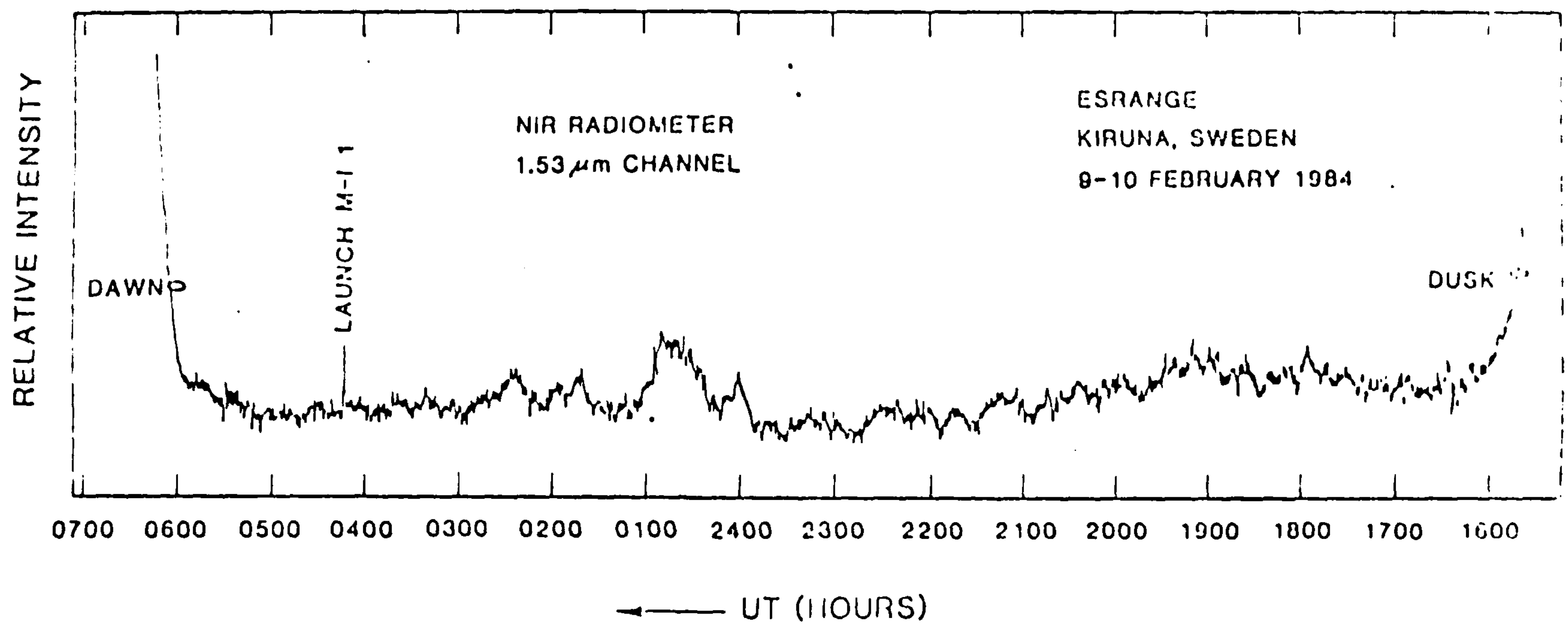
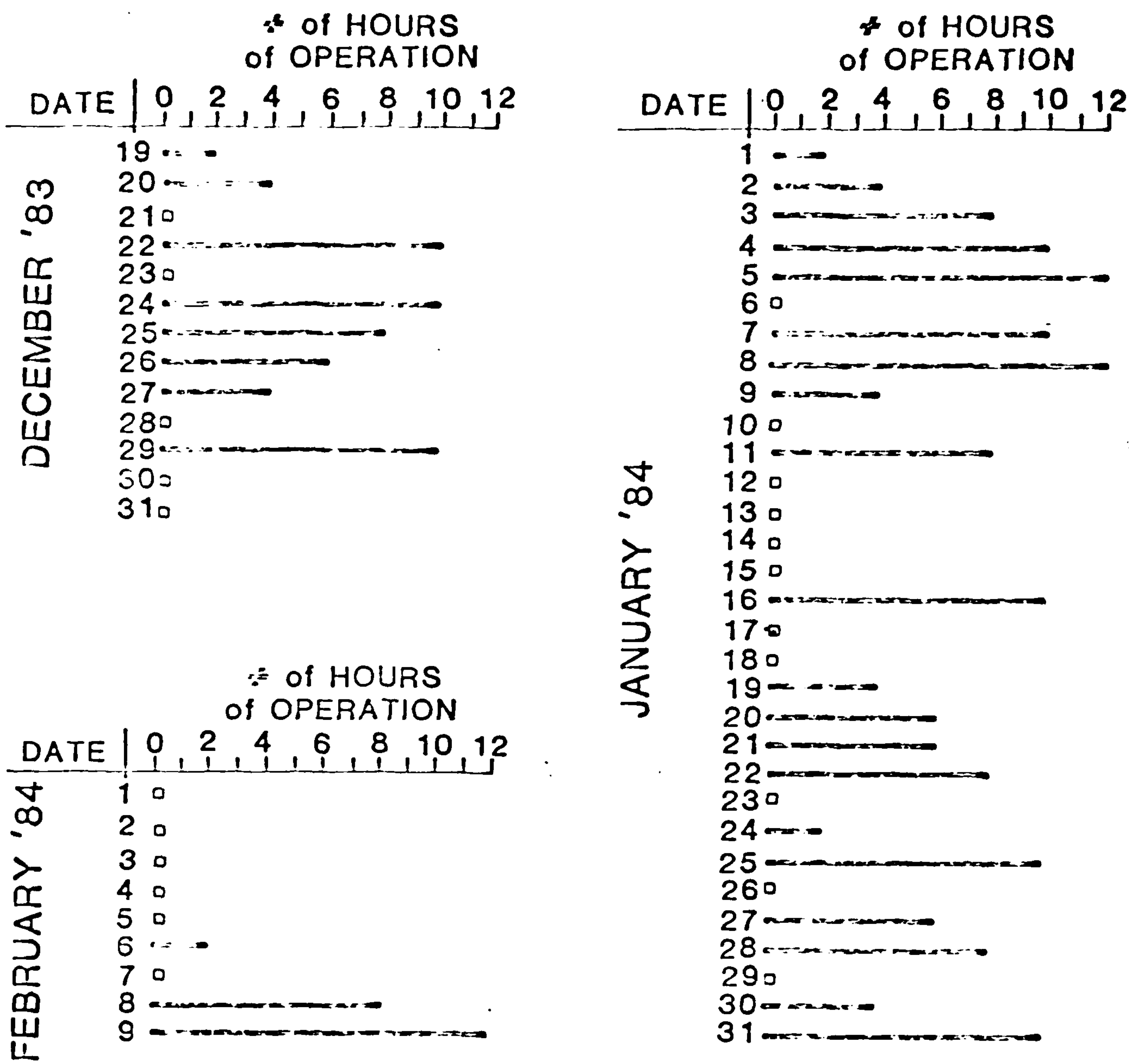

RELATIVE INTENSITY
DAWN
LAUNCH M-I 1
NIR RADIOMETER
1.53 μm CHANNEL
ESRANGE
KIRUNA, SWEDEN
9-10 FEBRUARY 1984
DUSK
0700 0600 0500 0400 0300 0200 0100 2400 2300 2200 2100 2000 1900 1800 1700 1600
UT (HOURS)

Fig 9

# USU MAP/WINE
## GROUND OBSERVATIONS
## Kiruna, Sweden




TOTAL OPERATIONAL NIGHTS ---------- 53

TOTAL NIGHTS WITH DATA ---------- 31

TOTAL HOURS OF INTERFEROGRAMS ---------- 220

TOTAL HOURS OF PHOTOMETER DATA ---------- 103

□ = 0 HOURS

Fig. 10

END

FILMED

12-85

DTIC